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(54) Title: METHOD FOR MAINTAINING GEOMETRY OF BALLASTED RAILROAD TRACK

(57) Abstract: This invention includes a method for estimating the shape of a section of railroad track from so-called chord offsets measured along it without prior assumptions about the locations and orientations of arcs and tangents that together could define a shape to which the track might be made to conform. This invention also includes a method for finding a configuration of tangents, arcs, and spirals that are as close as practical to a set of existing points along a section of track and that can define a desired shape for calculating instructions to a track lining machine.

METHOD FOR MAINTAINING GEOMETRY OF BALLASTED RAILROAD TRACK

BACKGROUND OF THE INVENTION

The phrase ballasted railroad track refers to railroad track that consists of steel rails mounted on top of support beams called ties that are perpendicular to the rails and that in turn rest on and are surrounded by a bed of small rocks called ballast. A bed of track ballast tends to change shape with time due to its lack of rigidity, due to settlement of the earth on which it rests, due to strains within the rails, and due to forces applied to the rails by passing railroad vehicles. As a result the shape of the guidance path provided by the rails tends to change and degrade with time, and maintenance needs to be performed from time to time to restore the shape of the rails. Such maintenance work is now normally performed using a large semi-automated tamping machine that is able under computer control to adjust the location of a few ties at a time (and the portions of rail that are attached to those ties) while agitating the ballast so that the ties are easier to move and so that the ballast tends to fill in around the adjusted tie locations. This invention has to do with the way that instructions for controlling the operation of such a tamper are computed.

Prior art relating to tamping ballasted railroad track is extensive. Here attention is limited to methods for calculating the lateral displacements between current and desired locations of points along a track. Such displacements are sometimes referred to as track throws.

Prior calculation of corrections to the horizontal geometry of a section of track was based on calculation of a desired location along the track for the start of each transition from tangent or circular arc to spiral and from spiral to another circular arc or back to tangent. Typically a computer program that an engineer or tamper operator uses for calculation of tamping instructions will analyze recently made measurements of track shape to estimate the locations for those transition points, may allow the engineer or operator to adjust

them, and will then calculate tamping instructions aimed at bringing the track shape closer to a form with transition points as specified. See, for example, U.S. Patent No. 4,012,413, entitled "Railroad track curve lining apparatus and method".

SUMMARY OF THE INVENTION

The method of this invention calculates a target track shape composed of tangents and arcs plus spiral transitions that fit together with both compass bearing and curvature continuous with distance and that together constitute a shape whose lateral displacements from points on the existing track are as small as possible with respect to a selected measure such as the root-mean-square.

The method of this invention also includes calculations to construct the existing shape of the track from so-called chord offset measurements when measurements of the existing track are in terms of such offsets rather than in terms of surveyed coordinates of points along the track with respect to a fixed coordinate system.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 illustrates a type of extrapolation that can be used to process offsets measured at intervals along an existing track so as to obtain coordinates of points along that track with respect to coordinate axes defined in relation to the track.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

1. Obtaining an Estimate of an Existing Track Shape.

For an application in which the existing shape of a section of track is known in terms of measured offsets rather than in terms of surveyed coordinates at points on the track it is necessary to obtain estimates of coordinates of points on the track by processing the offset data. The following paragraphs outline how this estimation can be performed when

the distance between track locations at which successive offset measurements are made is close to one sixth the length of the chord used for measuring the offsets. In this case the measured offset values can be separated logically into two sets that are relatively independent of one another. If the distance between track locations at which successive offset measurements are made is close to some other fraction of the length of the chord, then the number of relatively independent sets into which the offset values separate will generally be different, and the details for averaging the results obtained from extrapolations of values of the independent sets are adjusted accordingly.

Referring to Figure 1, which illustrates half of the offsets, each offset is first modified so that neighboring even and odd offsets have approximately the same average curvature. This is to help minimize the tendency of offset measurement errors to cause points extrapolated from the two independent sets of offsets to become discordant.

Then, extrapolation is initialized by placing point a at an arbitrary point in the xy plane and placing point y so that a main circular arc through points a, x, & y has an arbitrary orientation. Point c is located along that main arc based on arc length from point a along another initializing circular arc through points a, b, & c whose curvature is varied slightly with respect to the curvature of the arc through points a, x, & y and which serves to locate point b in a manner that will be explained. Point b is located midway between points a & c on this other initializing arc. Point d is tentatively located on the main arc an arc distance chord_length/3 beyond point c.

As an illustration of how the extrapolation progresses, the front of the chord is then moved to point b and the chord is rotated so that a new main arc with curvature corresponding to the second offset passes through point y. The location of the back of the chord is recorded, point d is adjusted to be the mean of its tentative location and the point an arc length 2*chord_length/3 beyond point b on the new main arc, and point e is tentatively placed an arc length chord_length past point b on the new main arc.

The above steps are placed inside a loop in which the curvature of the initializing arc

governing points b & c is varied in a Newton search procedure to find the positioning of point b such that the disorder of the extrapolated line is minimized. This is necessary because the measured offsets do not give direct information about the placement of point b comparable to the good information that they give about the relative locations of other points within the set.

The above steps are carried out independently for the odd numbered offsets and for the even numbered offsets with a small curvature increment added to all the odd numbered offsets and subtracted from all of the even numbered offsets to further help prevent discord between the two independent sets of point coordinates extrapolated from the even and odd numbered offsets. Then the above steps are repeated inside an iterative search loop that varies both the amount of curvature shifted between sets and the positioning of the points extrapolated from the even numbered offsets relative to the points extrapolated from the odd numbered offsets in order to find the arrangement that minimizes the disorder of all the points taken together.

2. Fitting Target Geometry to an Existing Track Shape

Once the existing track shape is known either via survey or via estimation from measured offsets as exemplified above, the way that this invention determines the target geometry can be illustrated for the case of a single arc bounded by neighboring spirals bounded in turn by sections of tangent track as follows. The target geometry can include either traditional linear spirals or any of the several types of spiral that have been proposed as improvements. The target geometry is then specified by two parameters each for locating the two tangents (for example the compass bearing and depending on the value of the bearing either the x or y intercept) plus three parameters for locating the curve (two to locate the center and one for the radius) so that there are a total of seven parameters to be determined. (A spiral of a specified form is determined by the curvature of the curve and the offset between the curve and the tangent so that a traditional spiral or a simple improved spiral does not offer an additional parameter.) The parameters of the target geometry can be found by a simple Newton type iterative search process in which each

parameter is varied to find the configuration that minimizes a measure of the lateral track throws needed to move the track from the existing to the target shape. The foregoing procedure can be extended to cover progressive and reverse curves that include multiple arcs connected by spirals.

Once the target geometry has been calculated the lateral track throw from each extrapolated point on the existing alignment to the corresponding point on the target alignment is obtained by a simple trigonometry and can then be used for calculating instructions to a track lining machine.

It will be understood that various changes in the details which have been herein described and illustrated in order to explain the nature of this invention may be made by those skilled in the art within the principle and scope of the invention as expressed in the following claims.

CLAIMS

What is claimed is:

1. A method for processing coordinates of points along an existing track to obtain a desired track alignment defined by a sequence of tangent, spiral, and circular arc segments whose lateral distances from respective adjacent points on the existing track are minimized, comprising the steps of:

accepting instructions from a user specifying how many tangent and circular arc track segments should be incorporated into a desired alignment and specifying initial estimates for locations of the respective boundaries between those segments;

making initial estimates of positioning of tangents and of positioning and radii of arcs by means such as least squares fitting of each tangent or arc to the coordinates of the existing track points that lie within the boundaries of the latter;

carrying out iterative searching to find a configuration of tangents and arcs and along with said configuration a set of spirals that connect to them with continuous compass bearing and curvature such that based on a measure such as root mean square of transverse distances from adjacent existing track points the tangents, arcs, and spirals taken together are as close as practical to the existing track points;

adopting the said configuration of tangents and arcs as the desired alignment for a corresponding section of track; and

calculating instructions directing a track lining machine to adjust the track to conform to said configuration.

2. The method of claim 1 wherein, in the accepting step, a user is assisted by

computerlogic that processes the data defining an existing track shape to infer a possible sequence of tangent and arc segments to serve as initial estimates which the user can then accept or modify.

3. A method for processing offset measurements made along an existing track to obtain estimates of coordinates of points along that track that can be processed by the method of claim 1, comprising steps of:

choosing a pair of coordinate axes oriented for convenience to serve as a basis for expressing coordinates of points located along the track by extrapolation from the offset measurements; and

applying extrapolation to successive offset measurements with track curvature treated as constant for short distances along the track and thereby placing successive estimated track points relative to the chosen coordinate axes.

4. The method of claim 3 which further includes, for offset measurements which separate naturally into independent sets in the sense that coordinates extrapolated from offsets of one set do not depend on offsets of any other set, the step of applying averaging so that the estimated track coordinates of the various sets are adjusted to minimize the roughness of the resulting estimated track shape.

5. The method of claim 3 which further includes the step of averaging to compensate for an insufficiency of the offset data.

6. The method of claim 5 which further includes, for offset measurements which separate naturally into independent sets in the sense that coordinates extrapolated from offsets of one set do not depend on offsets of any other set, the step of applying averaging so that the estimated track coordinates of the various sets are adjusted to minimize the roughness of the resulting estimated track shape.

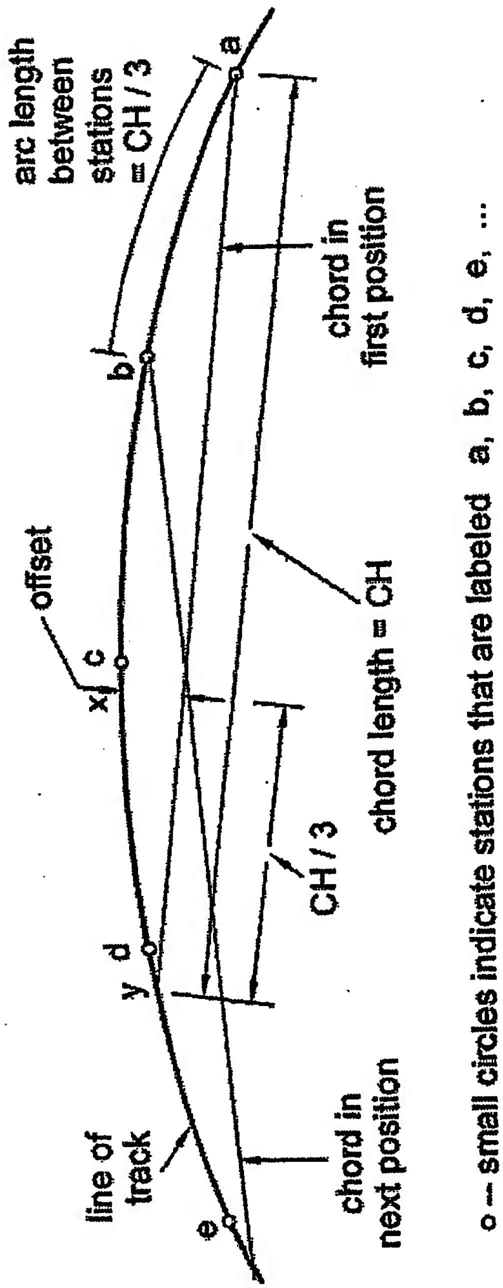
arc length between stations = CH / 3
a
b
offset
x
c
chord in first position
chord length = CH
CH / 3
y
d
line of track
e
chord in next position
o — small circles indicate stations that are labeled a, b, c, d, e, ...

Figure 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US05/14749

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : G06F 17/10
US CL : 703/2; 701/19; 104/7.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 703/2; 701/19; 104/7.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
IEEE Xplore, Inspec/Dialog, ACM Digital Library, ScienceDirect, WEST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,257,494 A (TOKUOKA et al) 10 July 2001 Background/Summary of the Invention.	1-6
A	US 5,012,413 A (SROKA et al) 30 April 1991, Background/Summary of the Invention	1-6
A	US 3,732,827 A (ANDERSON) 15 May 1973, Description of the Invention.	1-6
A	US 3,939,777 A (MORAN) 24 February 1976, Background/Summary of the Invention.	1-6
A	CLARK, R. Rail Flaw Detection: Overview and Needs for Future Developments, NDT & E International, Vol. 37, No. 2, March 2004, pp. 111-8	1-6
A	KRUEGER, H. et al Simulation within the Railroad Environment, Proceedings of the 32nd Conference on Winter Simulation, December 2000, pp. 1191-1200	1-6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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